



Ambient Groundwater Quality of the Yuma Basin: An ADEQ 1995 Baseline Study

I. Introduction

The Yuma Groundwater Basin (YGB), located in the southwestern corner of Arizona (**Figure 1**), is an area of startling geographic contrasts. Precipitation in this arid basin averages less than three inches annually, yet because of irrigation it is one of the world's most productive agricultural zones. Similarly, much of the YGB is uninhabited desert, yet the basin has a large, growing population that increases seasonally with the arrival of a large winter visitor (*snowbird*) population. A variety of water-related issues in the basin prompted the Arizona Department of Environmental Quality (ADEQ) to conduct a regional groundwater quality study of the YGB in 1995. This ADEQ factsheet is a summary of the more extensive ADEQ hydrology report available from the agency (1).

II. Background

The YGB encompasses more than 750 square miles at the apex of the Colorado River delta, approximately 70 miles north of the Gulf of California (2). The basin boundaries are formed by two hydrologic barriers, the Laguna Mountains to the northeast and the Gila and Tinajas Atlas Mountains to the east, and two political boundaries, the international border with Mexico to the south and west and the California border to the west (**Figure 1**).

The basin consists mainly of private and military lands with lesser amounts of various federal, State, and Tribal lands. The local economy is based upon agricultural (**Figure 2**), tourism, military, and manufacturing activities.

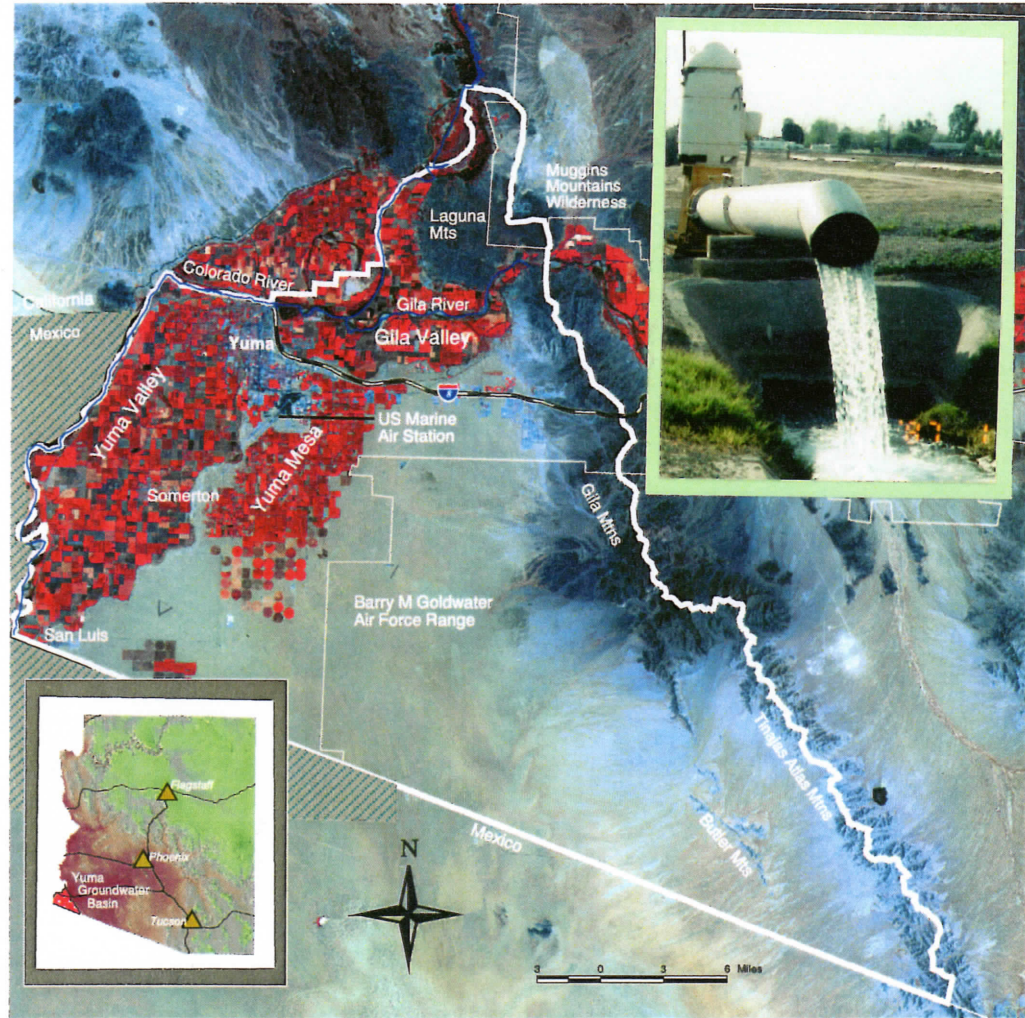


Figure 1. Irrigated farmland appears in crimson, desert areas are in beige, and mountains are in dark gray in this infra-red satellite image of the Yuma basin. Insets include an Arizona map highlighting the Yuma basin and a drainage well pumping excess water from irrigation applications.

Incorporated communities in the YGB and their 1998 populations include Yuma (67,443), Somerton (5,280), and the bi-national city of San Luis (4,212).

The Colorado River, which drains most of the southwestern U.S., forms the western boundary of the YGB. Though regulated upstream by a series of storage dams, the Colorado River is perennial as far south as the Morelos Dam, a diversion dam operated by Mexico approximately 11 miles downstream of the city of Yuma. The Gila River is also perennial through the YGB, typically serving as a natural drain for excess irrigation water in the area. Important sub-areas of the YGB and their extent include two river valleys: Gila Valley (27,000 acres) and Yuma Valley (65,000 acres), and a river terrace, Yuma Mesa (300,000 acres).

The largely undeveloped Yuma Desert occupies the remainder of the basin (2).

III. Hydrology

This study examines the groundwater quality in the two shallowest water-bearing units in the YGB. The **upper, fine-grained zone** consists largely of sand and silt with clay lenses found at shallow depths in the river valleys. This zone averages about 100 feet below the river valleys and 175 feet below the Yuma Mesa (2). Only a few domestic wells draw water from this zone, yet it is important because percolating water is recharged vertically through this uppermost layer. Underlying the uppermost zone is the **lower, coarse-gravel zone**, which also consists of alluvial sediments (2). Most Yuma-area wells draw water from this



Figure 2. The Yuma-area has the highest rate of pesticide applications in Arizona.

zone because of its high productivity. Groundwater is found in other formations below these two zones but is seldom used for water production and thus, not examined in this study.

The preferred water source in the Yuma area is the Colorado River, with around 700,000 acre-feet diverted annually at Imperial Dam for use in both Arizona and California (2). This surface water is the main source for both irrigation in the basin and municipal uses by the city of Yuma. Groundwater generally has higher salinity levels and is used for domestic or irrigation purposes only in areas where (or when) Colorado River water is unavailable.

The towns of Somerton and San Luis and some rural subdivisions and isolated residences utilize groundwater for domestic uses. Groundwater is also used for irrigation in limited parts of the Gila Valley and Yuma Mesa. Most groundwater pumped in the YGB is withdrawn by drainage wells (Figure 3) that are part of the extensive drainage infrastructure necessary to keep the Gila and Yuma Valleys from becoming water-logged. These wells, located along the interface between the valleys and Yuma Mesa, operate continuously to offset rising groundwater levels caused by the importation of Colorado River water. Drainage wells feed surface drains that transport the saline excess water to Mexico.

IV. Methods of Investigation

This study was conducted by the ADEQ Groundwater Monitoring Unit to characterize regional groundwater quality. Samples were collected at 55



Figure 3. The high productivity of the coarse-gravel zone is shown by this Gila Valley drainage well. The Yuma Mesa and Gila Mountains are seen in the background.

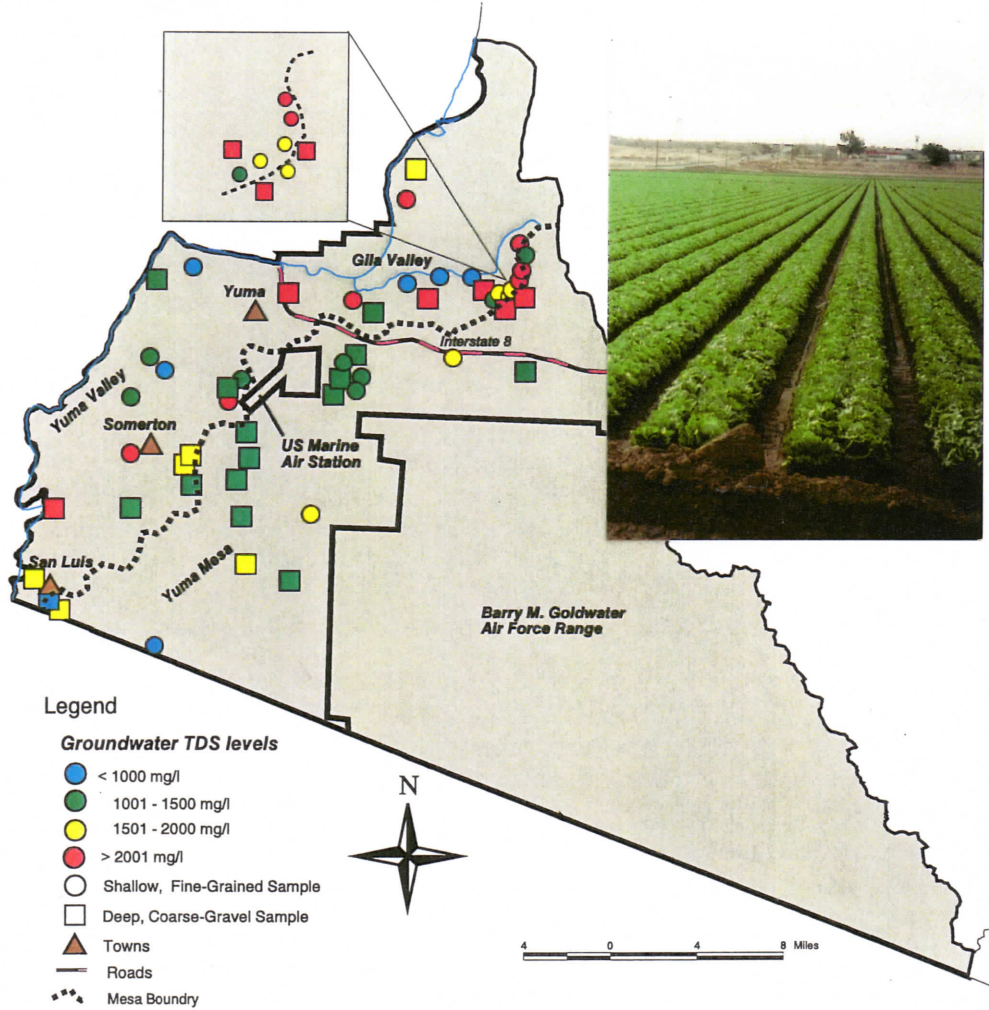


Figure 4. Total dissolved solids (TDS) levels vary throughout the basin but tend to be highest in Gila Valley. High salinity levels are the main limitation in using groundwater for domestic use. Inset image shows a lettuce crop in the Gila Valley just below the interface with the Yuma Mesa.

sites for inorganic constituents (Figure 4). At selected sites, samples were also collected for the banned pesticides, 1,2-dibromo-3-chloropropane (DBCP) and ethylene dibromide (EDB) (41 sites), currently-registered pesticides (21 sites), and radionuclides (7 sites).

Of the 55 total sites, 42 sites were randomly selected using a stratified design to equally distribute the wells in three YGB sub-areas (Gila Valley, Yuma Mesa, and Yuma Valley) as well as in two groundwater zones (upper, fine-grained and lower, coarse-gravel). The remaining 13 sample sites were targeted around specific land uses and an area of high nitrate levels. No sample sites were located in the southeastern portion of the basin within the Barry Goldwater Air Force Range. Sampling protocol followed the ADEQ *Quality Assurance Project Plan*.

Interpretation of the quality control data indicated that the effects of sampling equipment and laboratory procedures on the analytical results were not considered significant.

V. Water Quality Standards

The collected groundwater quality data was compared with federal Safe Drinking Water (SDW) standards. Primary Maximum Contaminant Levels (MCLs) are enforceable, health-based, water quality standards that public water systems must meet when supplying this resource to their customers. Primary MCLs are based on a lifetime daily consumption of two liters of water. Five of the 55 sites sampled had parameter levels exceeding a Primary MCL. All these exceedances involved nitrate levels, with four sites located in the eastern South Gila Valley.

Secondary MCLs are unenforceable, aesthetics-based, water quality standards that are guidelines for public water systems. Water with Secondary MCL exceedances may be unpleasant to drink, but it is not considered to be a health concern. All of the 55 sites sampled had parameters exceeding a Secondary MCL. Individual parameter exceedances included total dissolved solids or TDS (55 sites), sulfate (49

sites), chloride (32 sites), manganese (38 sites), and iron (7 sites). These results indicate that the chief limitation in using groundwater in the YGB is salinity, the extent of which is shown by variable TDS levels in **Figure 4**.

In the 41 samples collected for banned-pesticide analysis, there were no detections of either DBCP or EDB. Of the 21 samples collected for analysis of currently-registered pesticides, there were no detections of the 152 pesticides or degradation products on the ADEQ Groundwater Protection List.

VI. Groundwater Composition

Groundwater in the YGB is generally *slightly alkaline, slightly saline, and very hard* based on pH, TDS, and hardness levels, respectively. Major ion analyses reveal a consistent mixed chemistry of a sodium/calcium-sulfate/chloride type. Trace elements such as aluminum, barium, cadmium, chromium, copper, lead, mercury, silver, and zinc were rarely detected. In contrast, other trace elements such as arsenic, boron, fluoride, iron, manganese, and selenium were detected at more than 10 percent of the sites. Nitrate, a nutrient, was at levels in parts of Gila Valley and Yuma Mesa that indicate an impact from human activities. Ammonia, a nutrient typically not detected in other Arizona basins, was found at about half the sites and may be associated with the heavy use of ammonia fertilizer in the area.

The strength of association between levels of different parameters was assessed using Pearson's Correlation Coefficient test. Many significant ($p \leq 0.05$) correlations among parameter levels were revealed. Positive correlations occur between TDS, major ions, total Kjeldahl nitrogen (TKN), boron, iron, and manganese. In contrast, these parameters often had negative correlations with pH.

Most groundwater in Arizona is oxidizing in nature, however the positive correlation ($p \leq 0.05$) of ammonia, iron, and manganese levels seems to indicate that reducing conditions exist in the YGB. Ammonia and iron were detected exclusively at sites in Gila Valley and Yuma Valley. The reducing conditions may be driven by the oxygen demand presented by decomposing soil organic carbon in the river valleys, which were once marshes. Reducing conditions would tend to increase the solubility of iron and

manganese and keep any nitrogen, contributed by heavy crop fertilizer applications, in the ammonia state.

VII. Groundwater Quality Patterns

Significant ($p \leq 0.05$) statistical differences were identified between parameter levels and basin sub-areas using an Analysis of Variance (ANOVA) test with the Tukey Option. Parameters such as TDS, calcium, magnesium, hardness (**Figure 5**), sodium, potassium, chloride, sulfate,

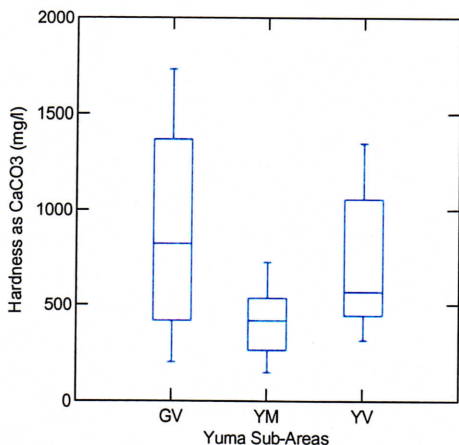


Figure 5. Boxplot shows hardness levels are highest in the Gila Valley (GV), lowest in the Yuma Mesa (YM).

TKN, iron, manganese, and turbidity had higher levels in the Gila Valley than Yuma Mesa. Other significant ($p \leq 0.05$) patterns include: sodium, fluoride, boron, and manganese were higher in Gila Valley than Yuma Valley; calcium, iron, and turbidity were higher in Yuma Valley than Yuma Mesa; and nitrate was higher in Yuma Mesa than Yuma Valley.

The ANOVA test was also used to examine for differences between water zones. The results indicated no significant ($p \leq 0.05$) differences among the levels of any parameters between the upper, fine-grained zone and the lower, coarse-gravel zone.

Although no significant differences were found between different water zones, regression analysis revealed parameters such as calcium, bicarbonate, sulfate, hardness, total alkalinity, nitrate, TKN, iron, manganese, and turbidity had levels that significantly ($p \leq 0.05$) decreased with increasing groundwater depth below land surface. These depth patterns may have been influenced by the

significantly ($p \leq 0.05$) greater groundwater depths found in Yuma Mesa than in the valleys. These data suggest that generally vertical variation is less important than spatial variation for parameter levels in the YGB.

VIII. Targeted Sampling

To further investigate a high nitrate level at a site in the eastern South Gila Valley, eight additional targeted sites were sampled. Of these, four sites exceeded the 10 mg/l Primary MCL nitrate (as nitrogen) standard, with 116 mg/l the highest level found (**Figure 6**). Potential sources of nitrate in this area include a commercial septic system as well as nearby vegetable crops which generally need higher inputs of nitrogen fertilizer than other types of crops.

IX. Groundwater Changes

A time-trend analysis was conducted by comparing groundwater quality data collected from the same 14 wells approximately 5 years apart. The wells, sampled in 1989-90 by the U.S. Bureau of Reclamation, were re-sampled by ADEQ in 1995. A Wilcoxon signed-rank test was used to examine for trends in 15 parameters. Only potassium and sulfate levels significantly ($p \leq 0.05$) differed, increasing over time.

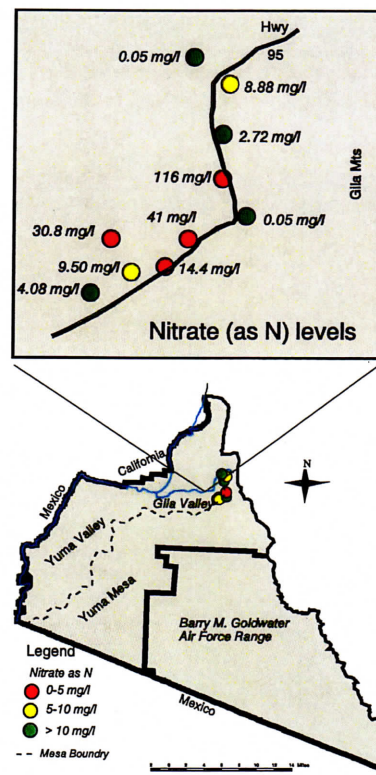


Figure 6. Nitrate levels in the eastern South Gila Valley are often elevated above health-based, drinking water quality standards.

X. Groundwater Conclusions

Comparing parameter levels with water quality standards suggests that regional groundwater quality conditions in the YGB generally support drinking water uses, except with nitrate in the eastern South Gila Valley. However because of high salinity levels, Yuma-area residents may prefer to use treated water or other sources for domestic purposes (Figure 7). Currently-applied pesticides do not appear to be migrating to the groundwater, perhaps because of their short half-lives. The banned pesticides, DBCP and EDB, which were detected in the early 1980s, appear to have been transported from the area via rapid groundwater movement in the basin.

Groundwater in the basin is fairly chemically uniform and similar to Colorado River water. This finding supports previous assertions that YGB groundwater consists largely of recharged Colorado River water (2). Parameter levels, particularly TDS and major ions, are generally highest in Gila Valley, decline in Yuma Valley, and are lowest in Yuma Mesa. Statistical analyses showed many of these differences to be significant and not merely happenstance. These patterns appear to result from a combination of irrigation development and physical factors unique to each sub-basin.

The source of irrigation water appears to be a major factor in Yuma-area groundwater quality. Colorado River water, diverted at Laguna Dam, has irrigated land in Yuma Valley and North Gila Valley since 1909. The Imperial Dam (Figure 8), constructed in 1938, largely replaced the functions of Laguna Dam. This dam extended Colorado River water for irrigation to the previously undeveloped Yuma Mesa in the 1940s and to portions of South Gila Valley in 1965, which had been irrigated with groundwater since 1910.

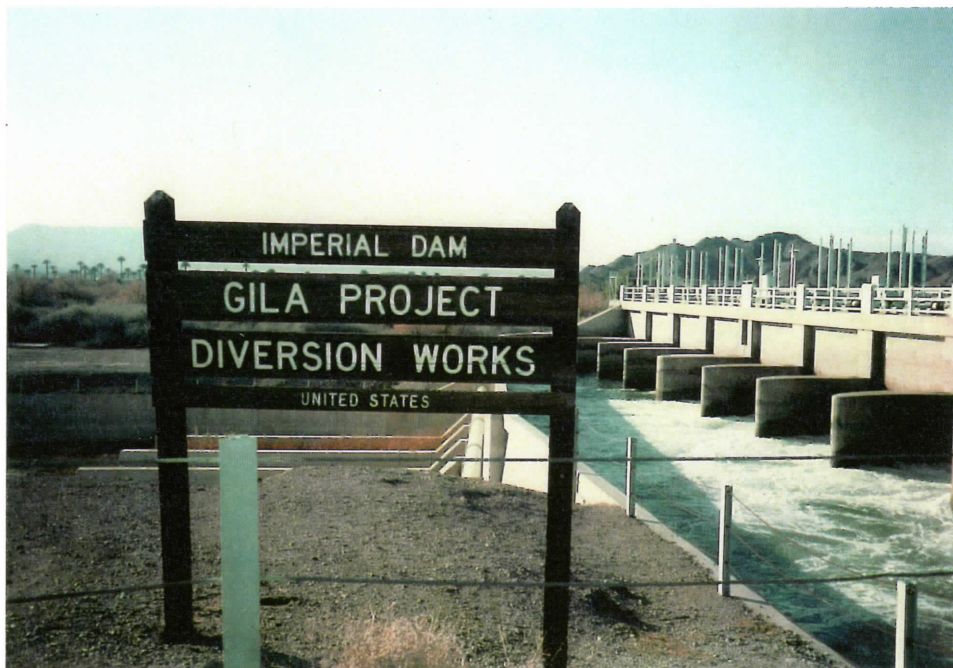


Figure 8. The Imperial Dam, located 18 miles northeast of Yuma, diverts Colorado River water into the Gila Gravity Main Canal for use in Arizona including the Yuma basin as well as into the All-American Canal for use in California. The dam, completed in 1938, replaced Laguna Dam.

Groundwater quality often deteriorates in arid irrigated areas due to salt buildup as a result of evapotranspiration (2). The portion of irrigation water that is actually consumed by plants or lost to evaporation is virtually free of salts. Thus, the vast majority of salts that were in the original irrigation water remain in the more saline percolating water that eventually recharges the underlying aquifer (3).

If groundwater is pumped for irrigation use on nearby lands and the underlying aquifer receives recharge from the irrigation water applications, this continual recycling of groundwater will dramatically increase the salinity of the aquifer over time (3). This process is exacerbated in areas of shallow groundwater where the recycling process occurs quickly, as appears to be happening in South Gila Valley (3).

In contrast, recharging aquifers with Colorado River water that is lower in TDS levels than the groundwater would tend to have less of a cumulative salt load. Water percolating beneath Yuma Mesa moves toward the valleys and is extracted by drainage wells, further minimizing the salt impact there. These processes assist in explaining the high baseline salinity levels found throughout the YGB, the particularly high salinity levels found in the Gila Valley where historically groundwater has been used for irrigation, and the salinity differences among sub-areas.

Other factors such as irrigation history, groundwater depth and movement, and soil type may also influence the Yuma

Mesa's generally lower parameter levels. Irrigation on the mesa is a more recent phenomenon, and groundwater depth is much greater. The high irrigation applications necessary to grow crops on the mesa's sandy soils (up to 22 acre-feet per year with citrus) quickly percolate. The resulting recharge and its associated salt load is largely flushed away from the groundwater mound that has formed below the mesa toward both valleys.

---Douglas C. Towne and Wang K. Yu
Maps by Larry W. Stephenson
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X. References Cited

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Figure 7. The Yuma-area has numerous vending machines dispensing Salt Free water, that is low in TDS levels, for domestic use.